Acoustical characterization of the riverine environment

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LONG-TERM GOALS

Develop a new capability in monitoring, understanding and predicting the dynamics of the riverine environment based on the characterization of the acoustical environment through *in situ* field observations and modeling which are closely linked to environmental measurements.

OBJECTIVES

Define and describe the acoustical characteristics of different riverine environments (e.g. braided (shallow, strong currents, gravelly bed), meandering (deep, weak currents, muddy bed)) using simple acoustic instrumentation, and correlate these acoustical characteristics to traditional riverine observational parameters (e.g. current profiles, geological descriptors).

Develop an acoustic propagation model to investigate the effect of the environment on the measured acoustic parameters, and validate the acoustic model with *in situ* field observations.

Through measurements and modeling, investigate the sensitivity of these acoustical-environmental correlations to frequency, and examine the temporal and spatial scales of variability in the riverine environment and its impact on signal coherence as a function of time, frequency and range.

APPROACH

The focus of the FY13 effort was preparation for and execution of one facet of the RIVET II field experiment—the acoustical characterization of the Mouth of the Columbia River (MCR) estuary. ‘MCR Acoustics’ consisted of a 2-week long cruise on the R/V Oceanus during the latter half of May.

WORK COMPLETED

Preparation for the MCR Acoustics field experiment included acoustical modeling of MCR based upon T&S profiles provided by the Center for Coastal Margin Observation and Prediction (CMOP) during a freshet period in May 2012 that was representative of the conditions expected during the cruise in May 2013. These modeling results not only informed planned placement of assets, acoustic signal

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transmission strategy and shipboard operations, but also on-the-fly decisions as experience was gained during the cruise. Some of the early modeling results have been published in Proceedings of Meetings in Acoustics (POMA) from the Montreal ASA meeting (Reeder, 2013). Preparation for MCR Acoustics also included the procurement of instrumentation (Acousonde hydrophones, SBE-30 TP sensors and MAVS acoustic current meters) and mooring hardware.

During the field experiment, multiple instrumented moorings and the tripod were deployed at strategic times and locations to facilitate the following objectives: (1) correlate ambient noise and acoustic signature statistics with measured physical parameters (current profiles and surface conditions); 2) characterize the contribution to the ambient noise environment by shipping traffic; and 3) investigate the acoustic propagation characteristics of the salt wedge.

The MCR estuarine environment proved to be dynamic, exciting and challenging. Since no observational low-frequency acoustic propagation work has been done in an estuarine environment like MCR, much was learned during this first field experiment in terms of logistics and observational strategies. The following is a short list of what was accomplished during the two-week cruise:

- deployed the tripod in two locations to collect T/P, current velocity and acoustic data
- deployed line moorings in 6 locations to collect T/P and acoustic data
- transmitted 500-2000 Hz LFM signals from the acoustic source at 3 locations
- completed a 26 hour CTD station near the South Jetty for CMOP model validation
- collected CTD data throughout the cruise at the three source stations
- collaborated with Jim Thomson (UW/APL) in the deployment of his SWIFT drifters, one of which was equipped with a hydrophone; strategic deployment of this drifter facilitated the collection of acoustic signals at a depth near the surface in the thin fresh water layer above the salt wedge.

RESULTS

Figure 1 shows some initial results from the experiment on May 27. The source was deployed at anchor station S2 (north side of channel, halfway between the North Jetty and Jetty A) and the signal was received by the Acousonde hydrophone on the tripod at mooring station A5 (1.36 km SSE of S2 on the south side of the channel). Two-second long linear frequency-modulated (LFM) signals having a 1500 Hz bandwidth (500-2000 Hz) were transmitted once every 10 seconds for a seven hour period (1500-2200Z/0800-1500 PST). This observation period occurred from the bottom of the ebb to the top of the flood during which the salt wedge front advanced from the point of greatest recession near the mouth to a point upriver of both source and receiver. The pulse-compressed output shown in Fig. 1 in terms of relative signal energy level (dB re 1 *u*Pa) averaged over 60-second moving windows exhibits a relatively gradual 15 dB decrease over the first 3-4 hours of the observation period followed by a more abrupt recovery of signal energy in approximately 1 hour. The initial hypothesis, yet to be verified by acoustic modeling, is as follows: The acoustic transect is initially composed entirely of fresh water, followed by the advance of the salt wedge along the bottom of the shipping channel; the salt wedge gradually fills the channel and then rises in the water column against the outward flow of fresh water. The denser salt water has a higher sound speed than the fresh water above it; this difference in sound speed causes acoustic refraction along the acoustic path. The acoustic signal

initially received at A5 is trapped in the thinning fresh water layer above the advancing salt wedge and above the receiving hydrophone at A5, resulting in the decrease in the observed signal energy level from 1600 to 1930Z. As the salt wedge continues to fill the water column between source and receiver, eventually displacing the fresh water layer at the surface, the observed signal energy level recovers during a relatively short 1-hour period. At 2026Z, the received signal energy abruptly increases approximately 6 dB as the salt wedge covers the entire acoustic path between S2 and A5, completing the 'acoustic circuit' such that minimal refraction and scattering losses are again observed, similar to conditions at the beginning of the observation period. The increase in variability between 1530 and 2030Z is likely due to the significant level of turbulence occurring along the salt wedge front as it crosses the acoustic transect; this hypothesis is subject to ongoing investigation.

Based upon an extensive literature search, these data constitute the first documented *in situ* acoustical observation of an estuarine salt wedge in terms of low-frequency acoustic propagation.

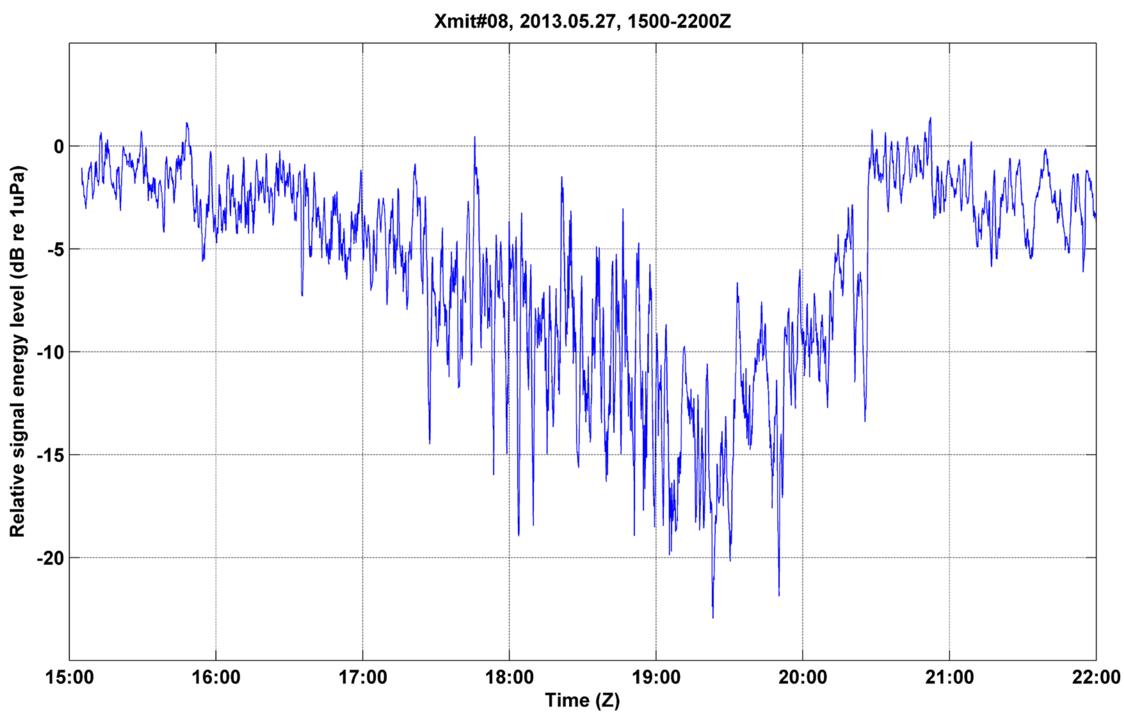

Fig. 1. Received relative signal energy level (dB re 1 uPa) vs time on May 27 from 1500 to 2200Z (0800-1500 PST).

IMPACT/APPLICATIONS

When correlated to the conventional riverine parameters, acoustic parameters will not only provide a deeper understanding of the riverine environment, but also the potential for new capabilities for remote persistent monitoring, rapid environmental assessment and environmental prediction.

PUBLICATIONS

Reeder, D. Benjamin (2013), "Acoustical characterization of the estuarine salt wedge", Proceedings of Meetings on Acoustics (POMA), 19/005004, doi:10.1121/1.4799122 (June).